STUDY ON THE MECHANICAL AND TRIBOLOGICAL BEHAVIOUR OF $Al/Al_2O_3/Gr$ HYBRID METAL MATRIX COMPOSITE PRODUCED BY POWDER METALLURGY

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SUPERVISOR'S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Master of Science.

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I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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ABSTRAK

Sejak kebelakangan ini, keperluan kualiti pelbagai fungsi bahan-bahan dalam industri automotif dan aeroangkasa memerlukan pembangunan bahan-bahan komposit ringan. Antara pelbagai jenis bahan, Aluminium (Al) dianggap sebagai salah satu pilihan yang popular daripada bahan-bahan lain kerana kebolehbentukan yang tinggi dan ringan sifatnya. Walau bagaimanapun, Al menunjukkan rintangan haus yang rendah di bawah keadaan pelincir yang tidak mencukupi yang mengehadkan penggunaannya dalam aplikasi tribologi. Oleh itu, bahan-bahan pelincir sendiri diutamakan kerana minyak pelincir pepejal yang terkandung di dalamnya boleh dikeluarkan secara automatik untuk mengurangkan haus semasa proses haus. Grafit (Gr) merupakan salah satu bahan yang mempunyai ciri-ciri pelincir yang tinggi. Walau bagaimanapun, kekangan bagi grafit yang ditambah dalam matriks aluminium ialah ia ketara mengurangkan kekuatan komposit tersebut. Oleh itu, satu penyelesaian yang boleh dilakukan adalah memperkenalkan bahan ketiga dalam komposit Al-Gr untuk meningkatkan kekuatan komposit tersebut. Alumina (Al_2O_3) merupakan salah satu bahan seramik yang popular digunakan dalam aluminium yang boleh meningkatkan kekuatan mekanikal. Isu yang paling penting dalam pembuatan komposit adalah untuk mengekalkan keseragaman zarah tetulang pada matriks logam. Kekuatan mekanikal yang ketara adalah dipengaruhi oleh kehomogenan zarah. Antara pelbagai teknik fabrikasi, metalurgi serbuk dianggap sebagai satu proses yang berkesan bagi membantu mencapai keseragaman. Oleh itu, dalam kajian ini, komposit hibrid terdiri daripada matriks aluminium dan Al_2O_3, pengukuhan Gr telah dibangunkan dengan teknik metalurgi serbuk dan kesan Al_2O_3 dan kandungan grafit ke atas tingkah laku mekanikal dan tribologi daripada hibrid komposit Al / Al_2O_3 / Gr telah dikaji. Dalam kajian ini, fabrikasi telah dijalankan dalam dua fasa. Dalam fasa pertama, aluminium-grafit (Al-Gr) komposit telah direka dengan nilai peratusan berat grafit yang berbeza dan ciri mekanikal dan haus telah dinilai dan nilai optimum grafit ditentukan. Selepas itu, MMCs hibrid telah dibina dengan menambah Al_2O_3 dan grafit tetulang zarah untuk bahan asas aluminium. Pada peringkat ini, peratusan zarah grafit dikekalkan malar (nilai yang memberi rintangan haus yang tinggi) digunakan tetapi peratusan Al_2O_3 tetulang diubah untuk mendapatkan sifat-sifat mekanikal yang tinggi. Serbuk mentah dengan peratusan yang dikehendaki dicampurkan, dipadatkan dan tersinter untuk mendapatkan komposit hibrid. Sampel yang telah direka kemudiannya disediakan untuk pencirian mikrostruktur, mekanikal dan ujian tribologi. Mikrostruktur telah menunjukkan satu ikatan yang sesuai dan taburan yang seragam untuk pengukuhan dalam matriks Al. Hasil kajian menunjukkan semua sifat-sifat mekanikal, termasuk kekerasan, kekuatan tegangan dan kekuatan lenturan bertambah dengan ketara dan sifat-sifat tribologi juga bertambah baik dalam komposit hibrid berbanding aluminium tulen dan Al-Gr komposit. Selain itu, hasil gabungan 10% Al_2O_3 dan 3% Gr menunjukkan prestasi yang tinggi dalam kedua-dua sifat mekanikal dan tribologi.

ABSTRACT

In recent years, the multifunctional quality requirements of materials in automotive and aerospace industries have necessitated the development of light-weight composite materials. Among the different types of materials, aluminium (Al) is considered as one of the popular choices of the materials due to its high formability and light-weight properties. However, Al shows low wear resistance under insufficient lubricating conditions which limits their use in tribological applications. Therefore, self-lubricating materials are preferred because the solid lubricant contained in them can be automatically released during the wear process to reduce the wear. Graphite (Gr) is one of the materials which possess high lubricating characteristics. However, the limitation of graphite in adding aluminium matrix is that it significantly reduces the strength of the composite. Therefore, one solution could be to introduce a third material to the Al-Gr composite to improve the strength of the composite. Alumina (Al_2O_3) is one of the popularly used ceramic materials whose introduction to the aluminium can increase the mechanical strength. The most important issue of composite fabrication is to maintain the uniformity of the reinforcement particles on the metallic matrix. The mechanical strength significantly influenced by the particles homogeneity. Among the various fabrication techniques, powder metallurgy is considered to be an effective process as reinforcements uniformity can be achieved by this. Therefore, in this study, hybrid composite composed of aluminium matrix and Al_2O_3, Gr reinforcements has been developed by powder metallurgy technique and the effect of Al_2O_3 and graphite content on the mechanical and tribological behaviour of the Al/Al_2O_3/Gr hybrid composite has been studied. In this study, the fabrication has been carried out in two phases. In the first phase, aluminium-graphite (Al-Gr) composites with different weight percentage values of graphite were fabricated and their mechanical and wear properties were evaluated, and the optimum value of graphite was determined. After that, hybrid MMCs was fabricated by adding Al_2O_3 and graphite reinforcement particles to the aluminium base material. At this stage, the percentage of the graphite particles kept constant (the value provided high wear resistance) but the percentage of Al_2O_3 reinforcement varied in order to get the high mechanical properties. The raw powders with the desired percentage were mixed, compacted and sintered to get the hybrid composites. The fabricated samples were then prepared for microstructural characterization, mechanical and tribological tests. The microstructure showed a proper bonding and uniform distribution of the reinforcement in the Al matrix. The results revealed that all the mechanical properties, including hardness, tensile strength and flexural strength increased significantly and the tribological properties tremendously improved in the hybrid composite as compared to the pure aluminium and Al-Gr composite. Moreover, the combined effect of 10% Al_2O_3 and 3% Gr displayed superior performance in both the mechanical and tribological properties.

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LIST OF SYMBOLS

b	Width
h	Height
k	Dimensionless wear coefficient
L	Length
P	Pressure
s	Sliding distance
V	Volume
σ_B	Bending stress

LIST OF ABBREVIATIONS

AA	Aluminium alloy
Ag	Silver
Al	Aluminium
Al_2O_3	Aluminium oxide/ Alumina
AMC	Aluminium matrix composite
ASTM	American Society for Testing and Materials
B_4C	Boron carbide
CNT	Carbon nanotube
Cu	Copper
Fe	Iron
GNP	Graphene nano-platelets
Gr	Graphite
Mg	Magnesium
MMC	Metal matrix composite
MoS_2	Molybdenum disulphide
MPa	Megapascal
Ni	Nickel
PVA	Polyvinyl alcohol
rpm	revolution per minute
SEM	Scanning electron microscope
SiC	Silicon carbide
SiO_2	Silicon dioxide
TiB_2	Titanium diboride
TiC	Titanium carbide
TiO_2	Titanium dioxide
UTM	Universal Testing Machine
WC	Tungsten carbide
Wt%	Weight percentage
XRD	X-ray diffraction

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